Variation in contaminant content of livers from Cormorants Phalacrocorax carbo sinensis living nearby a polluted sedimentation area in lake IJsselmeer, The Netherlands

Platteeuw, Maarten; van Eerden, Mennobart R.; van de Guchte, Kees

Published in:
Ardea

Publication date:
1995

VARIATION IN CONTAMINANT CONTENT OF LIVERS FROM CORMORANTS *Phalacrocorax carbo sinensis* LIVING NEARBY A POLLUTED SEDIMENTATION AREA IN LAKE IJSSELMEER, THE NETHERLANDS

MAARTEN PLATTEEUW[1,2], MENNOBART R. VAN EERDEN[1] & KEES VAN DE GUCHTE[3]

ABSTRACT The livers of 23 Cormorants drowned in fishing gear in the vicinity of the contaminated lake Ketelmeer, part of the lake IJsselmeer area, The Netherlands, were analysed for contents of a series of heavy metals and chlorinated hydrocarbons. Individual differences found were related to age, sex and apparent individual differences in food choice. Not surprisingly, contaminant levels were found to be generally lower in immature birds than in adult birds. Sex-related differences were slight and only noticeable in some of the compounds analysed. Comparing the results with data on contaminant loads in different prey fish species in the same area, it was suggested that an increase in the proportion of Eel in the diet might cause up to a twofold increase in contaminant level in some organochlorine compounds.

[1]Rijkswaterstaat Directorate Flevoland, P.O. Box 600, NL-8200 AP Lelystad, The Netherlands. [2]Zoological Laboratory, University of Groningen, P.O. Box 14, NL-9750 AA Haren, The Netherlands. [3]Ministry of Transport and Public Works, Institute for Inland Water Management and Waste Water Treatment (RIZA), P.O. Box 17, NL-8200 AA Lelystad, The Netherlands.

INTRODUCTION

The Dutch lake IJsselmeer, after having been closed off from the Wadden Sea in 1932, has rapidly become fresh by influence of the river IJssel. This northern Rhine branch enters the area near the town of Kampen (Fig. 1). Especially since the reclamation of two large polders on both sides of the IJssel delta (Noordoostpolder in 1942 and Oostelijk Flevoland in 1957), the 3800 ha lake in between, called lake Ketelmeer, has received a considerable amount of sediment: some 0.010 m per year (Winkels *et al.* 1990). The total amount of sediment deposited in lake Ketelmeer since the enclosure of lake IJsselmeer in 1932 is estimated at 1.5×10^7 m^3. Loam generally carries the highest amounts of pollutants like heavy metals, chlorinated biphenyls (PCBs) and polyaromatic hydrocarbons (PAHs). Therefore it is not surprising that an extensive analysis of the Ketelmeer sediment during 1987-1989 revealed unacceptably high concentrations of several of these toxic compounds (Winkels *et al.* 1990, Winkels & Van Diem 1991).

Lake Ketelmeer has been used as fishing water by breeding Cormorants *Phalacrocorax carbo sinensis* since even before the reclamation of the Noordoostpolder (Van Dobben 1952) and ever since (Veldkamp 1986, 1991). In summer this area is regularly visited by birds from two breeding colonies, Wanneperveen in nearby Overijssel and (especially on windy days) Oostvaardersplassen further south-west (Fig. 1). The area is also being exploited outside the breeding season (Platteeuw *et al.* 1992) and then wintering birds from abroad are involved as well.

As part of an ecological study on the toxicological risks of living in this polluted area, the livers of 23 Cormorants found dead in or near lake Ketelmeer have been analysed individually for a series of pollutants. This paper summarises the results of these analyses and tries to relate individu-

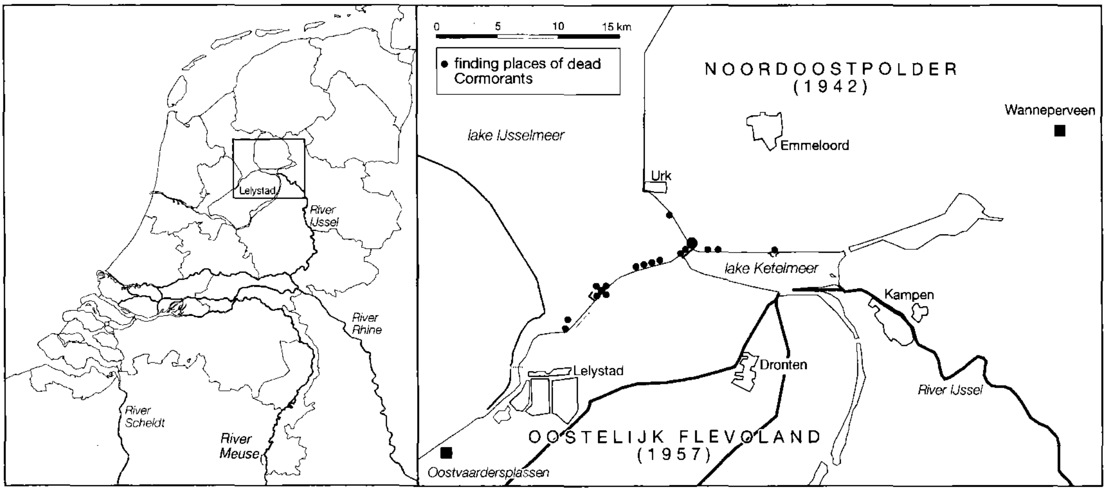

Fig. 1. Situation of study area (lake Ketelmeer and southeastern lake IJsselmeer) in The Netherlands with location of finding places of dead Cormorants (n = 23); the two nearest Cormorant breeding colonies (Oostvaardersplassen and Wanneperveen) are also indicated.

al differences in pollutant levels to factors as age, sex, physical condition and pollutant levels in the fish species consumed.

MATERIAL AND METHODS

The corpses of the Cormorants analysed were obtained from fishermen who had accidentally caught them in gillnets and fykes or found dead along the dikes after having been thrown overboard and subsequently washed ashore. The finding places of the 23 birds are indicated in Fig. 1. All birds analysed were found in late winter or early spring, before onset of breeding (mostly February-March). Out of 23 birds, 22 individuals were sexed and aged: 8 adult males, 8 adult females, 4 first year (until first summer) males and 2 first year females. Of all birds the following measurements were obtained: body length (cm), wing length (cm), bill length (0.1 mm), bill depth (0.1 mm) (for methods see Koffijberg & Van Eerden 1995), dry body mass (0.1 g) and total fat deposits (g), determined by a 7 days Soxhlet extraction with petroleum ether.

The livers of the 23 Cormorants were carefully removed and stored at -20° Celsius. Total mercury and arsene were measured using flameless AAS after destruction with salpetric acid, copper using graphite oven AAS, zinc using flame AAS and cadmium and lead using differential pulse anodic stripping voltametry. Organochlorine compounds were determined by means of gas chromatography with ECD detection, HCHs were measured on a GC/MS and PAHs were analysed by means of HPLC with fluorescention detection. A more detailed description of these analyses is given by Pieters (1991).

For each of the dissected Cormorants containing identifiable fish remains in the oesophagus, size and species composition of the birds' last meal were determined by identifying and measuring the fish remains found (for methods see Platteeuw 1985). The average daily ration (energy needed per day) was estimated as well, based on (reconstructed) fresh body mass (see Platteeuw & Van Eerden 1995 for methods), and expressed in terms of kJ.day^{-1}. Energy contributions to the average daily ration of each of the prey species found were estimated on relative abundance in individual gizzards, using prey specific caloric values as found by Platteeuw (1985). Assuming the

Table 1. Pollutant levels in livers of 23 Cormorants (mean, *SD* and *n* without two outliers; maxima include the outliers) found near lake Ketelmeer, The Netherlands.

		mean	*SD*	*n*	max
dry matter (g/kg)		274.3	19.19	23	332
lipid (g/kg)		42.1	12.65	23	71.5
Hg (mg/kg dry mass)		59	42.04	21	177
PCBs (µg/kg lipid)	IUPAC-no				
	31	27	44.61	21	64394
	28	1456	1522.13	21	299242
	52	661	1108.83	21	367424
	49	208	355.69	21	227273
	47	1684	1848.10	21	134969
	66+95	5200	4935.69	21	254601
	101	1210	1580.37	21	871212
	56	55	34.29	19	140
	97	718	753.03	21	53030
	87	128	240.87	13	7669
	85	1873	1809.02	19	156442
	110	374	424.68	21	321970
	151	1144	4370.94	21	359848
	149	914	1277.22	21	833333
	118	11687	11942.86	21	833333
	153	35350	36405.02	21	4886363
	105	3922	4096.93	21	279141
	141	371	550.84	21	568182
	137	778	715.48	19	52147
	138+163	20938	21235.89	21	2537878
	187	8648	10054.13	21	1060606
	202	2065	7505.66	21	35519
	128	3025	3022.32	21	314394
	156	2259	2147.50	21	234848
	180	15580	20040.75	21	2121212
	170	7587	9356.89	21	909091
	194	1472	2170.55	21	178030
	206	316	344.02	21	36810
Organochlorine pesticides (µg/kg lipid)					
QCB		493	477.22	21	106061
HCB		1964	2018.10	21	492424
Octachloo		1539	1851.97	21	106061
α-HCH		222	130.87	21	833
β-HCH		678	712.42	21	21212
γ-HCH		186	138.09	21	1629
Dieldrin		1305	1996.13	21	45455
Endrin		23	9.56	21	35
Hepo		9	3.82	21	14
PP-DDE		20693	23279.72	21	1022727
PP-DDD		277	576.53	21	102273
PP-DDT		23	9.02	21	1043
PAHs (mg/kg lipid)					
acenaftene		0.216	0.0620	21	0.417
fluorene		0.025	0.0066	21	0.038
fenantrene		0.098	0.0269	21	0.140
antracene		0.170	0.0474	21	0.246
fluorantene		0.593	0.1849	21	0.877
pyrene		0.624	0.1661	21	0.947
b(a)antracene		0.192	0.0554	21	0.281
chrysene		0.073	0.0193	21	0.114
b(e)pyrene		0.073	0.0193	21	0.114
b(b)fluorantene		0.229	0.0597	21	0.455
b(k)fluorantene		0.050	0.0133	21	0.076
b(a)pyrene		0.025	0.0066	21	0.038
di-b(a,h)antracene		0.171	0.0460	21	0.246
b(ghi)perylene		0.075	0.0199	21	0.114
i(123cd)pyrene		0.064	0.0439	21	0.455

prey species composition found in each individual was indicative for its food choice in general, a conservative estimate was made of the total amount of some PCBs and organochlorine pesticides ingested in each meal as well as of the contribution of each prey species to these amounts. For these estimates measurements of pollutant levels in Eel *Anguilla anguilla* (in 1989), and Ruffe *Gymnocephalus cernua* and Smelt *Osmerus eperlanus* (in 1986) from lake Ketelmeer were used (Pieters 1990). Pollutant levels in other fish species (i.e. Perch *Perca fluviatilis*, Roach *Rutilus rutilus* and Pikeperch *Stizostedion lucioperca*) were estimated as the mean contents on lipid base found for Ruffe and Smelt, and recalculated on product base using lipid contents of these species as found by Platteeuw (1985).

RESULTS

Average pollutant levels

Average pollutant levels in the Cormorant livers analysed are summarised in Table 1. While organochlorine pesticides, mercury and most PCBs reached fairly high average levels, it became apparent that PAHs hardly, if at all, reached detection levels. The most remarkable result, however, was the striking amount of individual variation in

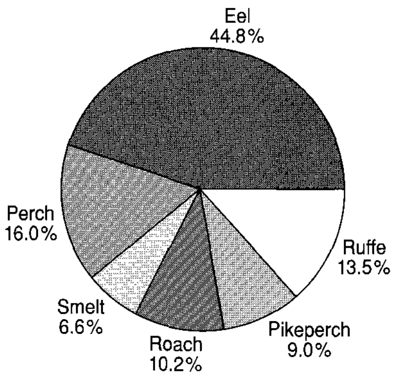

Fig. 2. Relative contributions to the energy content (in kJ) of the total amount of fish retrieved from the Cormorants' oesophagi by each of the prey species identified.

pollutant levels among the birds analysed, from almost nil to very high.

Two birds were found to contain much higher pollutant levels than all others and are considered to be outliers. Mercury contents in these birds were almost 3 times higher than the overall average and even 18 times higher than the lowest level measured. The levels of PCBs and organochlorine pesticides were generally 10-22 times higher than overall average (the only exception being PCB 56 that was a mere 2.6 times higher) and even up to 260 000 times more than the minimum level (PCB 151). The only compounds that did not show higher residue levels in these two outliers were α-HCH, γ-HCH, Endrin and Heptachlorepoxide. For comparison of average values between age and sex classes these two birds were excluded from further analysis.

Prey species and estimated intake of contaminants

The overall prey species composition on energy basis in the Cormorants analysed showed a large contribution of Eel (almost 50% of the energy needs) and a rather less important contribution by other fish (Fig. 2). Since the birds were found in early spring, seasonal differences in prey choice (e.g. Platteeuw *et al.* 1992) were of no importance. Nonetheless, individual differences in prey species composition of the last meal were considerable, varying from no Eel at all in some birds to meals consisting exclusively of Eel in others. After extrapolation of the prey species composition on energy basis of each bird's last meal to its estimated average daily ration, significantly positive correlations between the amount of Eel and the amount of PCBs in an average meal were found for all compounds considered, except for PCB 28 (Fig. 3). Since PCBs and most other lipophilic organochlorine compounds generally occur together in animal tissue in mutually positively correlated concentrations, these relationships may be generalised to all these compounds.

Differences related to sex and age

For almost all compounds levels of the adult birds were considerably higher than of the imma-

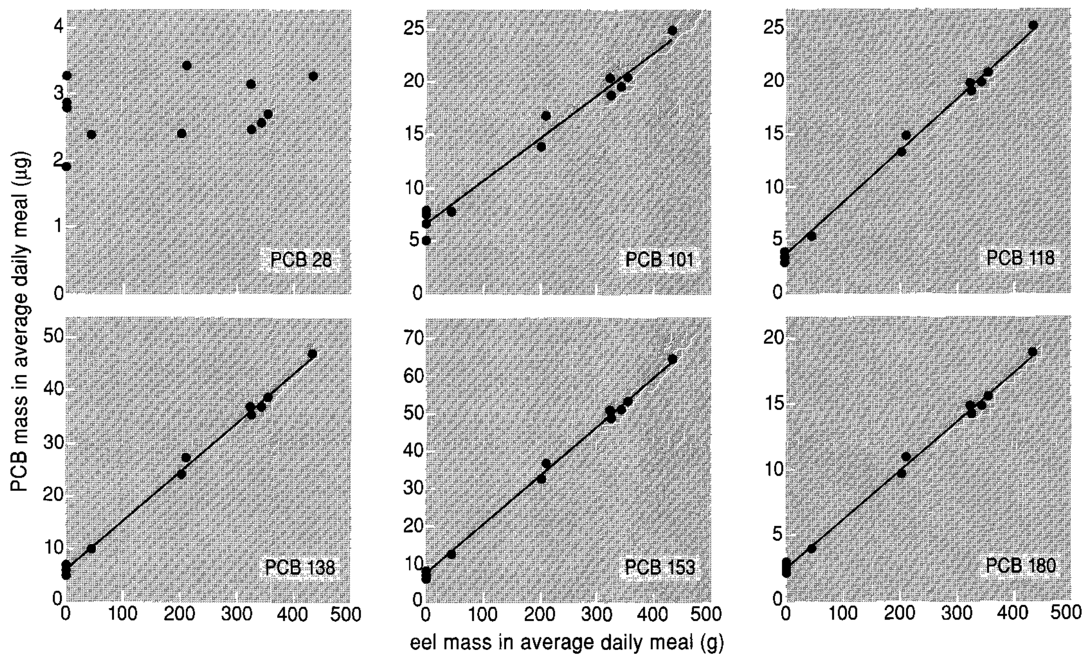

Fig. 3. Relationship between fresh mass of Eel in an average daily meal and the estimated amount of a series of polychlorinated biphenyls (PCBs) in the same meal.

tures, the only remarkable exceptions being QCB and α-HCH which showed comparable levels in both age categories (Fig. 4; for the latter compound see also Scharenberg & Schultz 1992). The amount of variation in contamination level was also generally higher among adult birds, except for p,p'-DDT which is metabolised. Excluding p,p'-DDT, the ratio *SE* in adults/*SE* in immatures ranged in all compounds from 0.2 (only value below 1, occurring for QCB in females) to 98, with an average of 15.

Sex related differences were much less pronounced, less consistent and hardly ever significant (Fig. 4). Only the level of γ-HCH was significantly lower in adult females than in adult males. Although not significant, the same trend of higher levels in adult males was shown for p,p'-DDD and HCB.

Differences related to physical condition

The levels of some of the contaminants in the livers showed clear negative correlations with the fat deposits of the birds, expressed in percentage of dry mass (Fig. 5). This was especially true for PCBs 28, 153 and 180, HCB, p,p'-DDE and β-HCH. Other organochlorine pesticides, like pp-DDD, p,p'-DDT, α-HCH, γ-HCH and Dieldrin, on the other hand, did not correlate at all with fat percentage of the birds (Fig. 5).

For most compounds a remarkable negative relationship existed between the levels detected in the livers of the birds and the size of their last meal, which, however, could not be established for some of the less lipophilic compounds (e.g. α-HCH; Fig. 6). The most contaminated birds had eaten fewer fish. This suggests that these birds were less successful feeders.

DISCUSSION

Average concentrations and individual maxima of contaminants like some of the PCBs and the more lipohilic organochlorine pesticides as p,p'-DDD

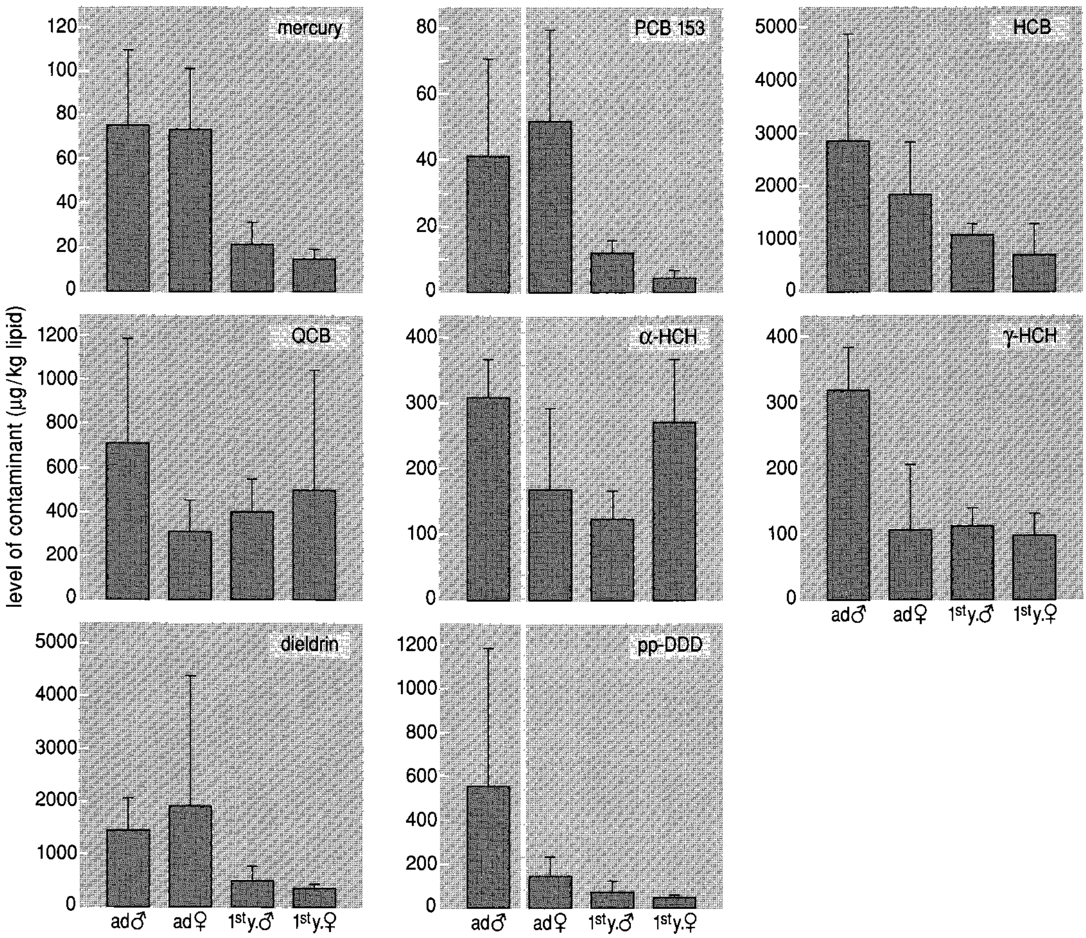

Fig. 4. Comparison of the average levels of contaminants as determined in the liver, according to age (adult or first year) and sex (male or female); 95% confidence limits are indicated. Mercury expressed as μg/kg dry mass, other contaminants as μg/kg lipid.

and p,p'-DDE in the livers of Cormorants reached levels which are considered to pose a threat to individual bird reproduction and therefore on the population as a whole (Koeman *et al.* 1973, Dirksen *et al.* 1991, Van der Gaag *et al.* 1991, Scharenberg & Schultz 1992). Derived No Effect Concentrations are surpassed by a factor 2-8. Some levels (e.g. total PCB content) are possibly even lethal (Koeman *et al.* 1973). Average concentrations in the livers, even excluding the outliers, of the lipophilic compounds are found to be about a factor 10-100 higher than average levels, also on a fat mass basis, in their food (Pieters 1990). Similar values were found in German Cormorant livers by Scharenberg & Schultz (1992). This confirms the rules of thumb for top-predator food-chain accumulation. The fact that higher levels of lipophilic compounds are found in adult birds than in young, also corroborates the model of the typical food-chain accumulation. In less lipophilic compounds like α-HCH differences with age in accumulation are markedly less pronounced. It may thus be stated that, as yet, no equilibrium is reached in the Cormorant between the rates of up-

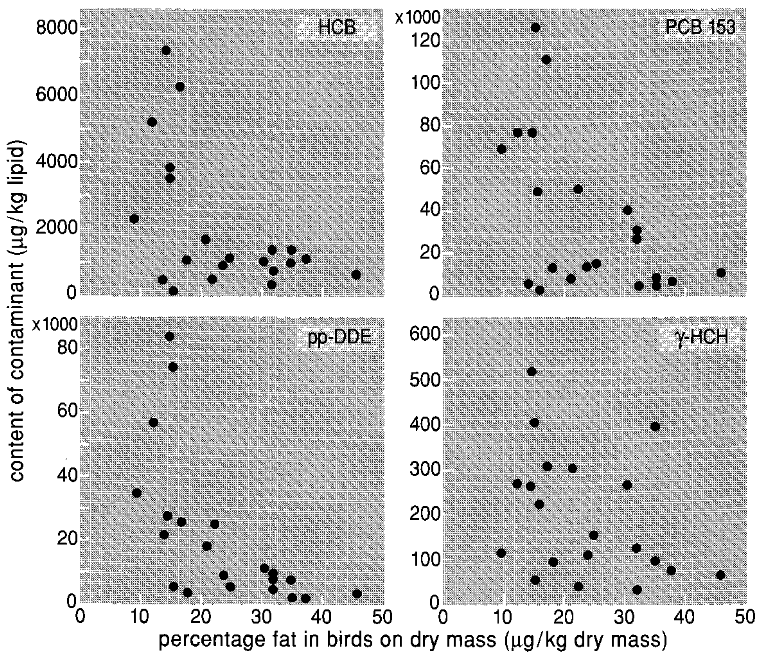

Fig. 5. Relationship between fat content (on basis of dry body mass) of Cormorants and the levels of some compounds in the liver.

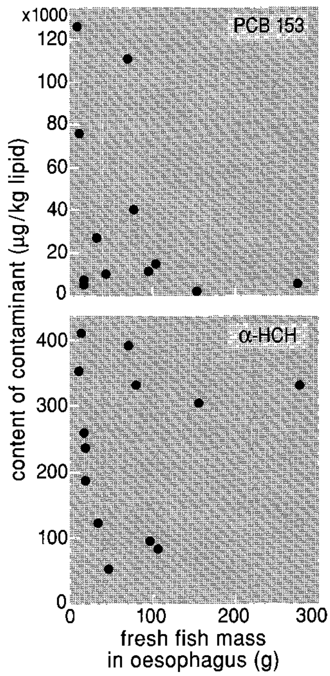

Fig. 6. Relationship between size of last meal (expressed as fresh fish mass in oesophagus in g) and the levels of two organochlorine compounds.

take and elimination of lipohilic contaminants. Both uptake and elimination in a homoeothermic and largely terrestrial animal like the Cormorant are only dependent upon metabolic rate, which, in its turn, is mainly dependent upon body mass (Aschoff & Pohl 1970). Thus, it is unlikely that the small individual differences in body mass can explain the high individual differences in pollutant levels. The slight differences in contaminant level between adult males and adult females found for some compounds may be caused by the fact that the males, being larger and more powerful, tend to catch larger Eel (Koffijberg & Van Eerden 1995) which is likely to be more contaminated. Deposition of contaminants in eggs by females occurs to a large extent (Van der Gaag *et al.* 1991, Van den Berg *et al.* 1995). This will, however, only be noted on fat basis in case of selective allocation of the most contaminated lipid reserves in the production of the eggs. It has been suggested that such a process might take place in Oystercatchers *Haematopus ostralegus* (Everaarts *et al.* 1991).

Individual differences in bio-accumulation among adult Cormorants, disregarding the two outliers of about a factor 2-5, may also partly have resulted from individually different foraging strategies or techniques. Several observations have indicated that, although the bulk of the Cormorants usually fishes socially, thereby catching predominantly the most abundant fish species available (Van Eerden & Voslamber 1995), there are always some individuals which prefer a solitary approach. These latter birds are probably food specialists and are likely to have a rather different prey choice, in which Eel plays an important role (Voslamber *et al.* 1995). The amount of higher chlorinated PCBs ingested per day varies according to the relative contribution of Eel to the daily ration. This variation may be as high as a factor 8-10 in PCBs 153 and 180 respectively (Fig. 3), due to the fact that Eel, being about the fattest fish species present, contains on product basis higher levels of these lipophilic pollutants than the alternative prey species like Roach, Perch and Ruffe (Pieters 1991). Thus, a Cormorant that consistently catches a larger proportion of Eel than its conspecifics is more likely to reach high levels of lipohilic pollutants. In fact, within this sample of birds, the proportion of Eel in the last meal on fresh mass basis showed a slight positive correlation with the levels on fat basis of some lipohilic compounds in the livers (Fig. 7). Thus, it appears that differences in prey choice may be consistent enough for these compounds to produce a twofold increase of bio-accumulation. For most of the compounds this is about the same variation as actually found. On the other hand, even the most extreme and consistently maintained difference in diet cannot, by itself, account for the extremely high contamination levels in the two outliers. In addition to a strict diet of highly contaminated fish, these birds may have been very faithful to one particular feeding site, severely polluted (e.g. lake Ketelmeer), throughout their lifetime. In general, however, most Cormorants are migratory and therefore subject to variable levels of environmental pollution at different seasons.

The general negative relationship found between liver contamination and physical condition of the birds (as expressed by fat content as well as by size of their last meal) can be understood in the following way. As long as Cormorants can maintain a good food intake and have no need to rely on their fat deposits, contaminants are stored away with fat and remain unused. As soon as birds start using their fat deposits, thereby mobilising the contaminants accumulated, their physical condition is bound to decrease more quickly when the pollutant load is higher. Then a highly contaminated bird gets progressively weaker and less able to catch sizeable meals to recover. A Cormorant is only likely to recover its condition, if the contamination load is relatively low. Alternatively, higher contamination levels may cause a decreased physical condition, resulting in smaller meal sizes and correspondingly lower fat deposits.

It can be concluded that colonial fish-eating birds like Cormorants are useful indicators of actual occurring food chain accumulation of lipophilic contaminants (cf. Dirksen *et al.* 1991, Fox *et al.* 1991, Van der Gaag *et al.* 1991, Van den Berg *et al.* 1995, Van de Guchte 1993). However, for birds having a large heterogeneous habitat it appears to be of importance to take into account variation among individuals, rather than to rely upon average contaminant levels.

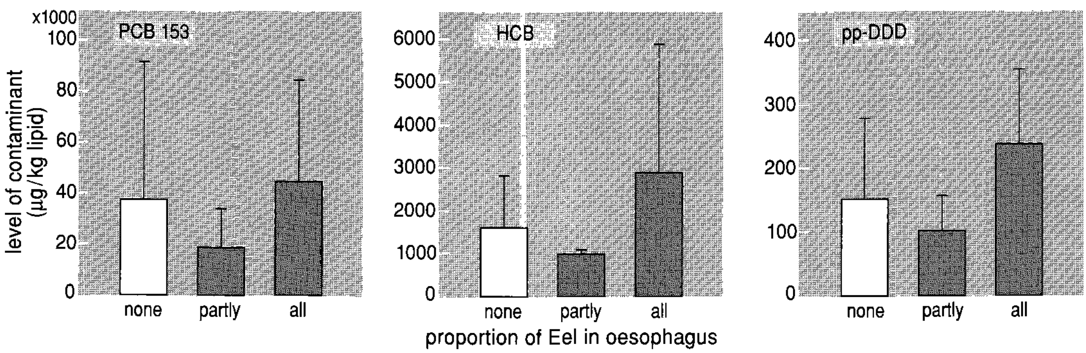

Fig. 7. Comparison of the levels of three organochlorine compounds in Cormorants with different proportions of Eel in their oesophagus. Categories are: no Eel, partly Eel and exclusively Eel; 95% confidence limits are indicated.

ACKNOWLEDGEMENTS

The analyses of the livers have been carried out by H. Pieters (Research Institute for Fisheries RIVO); assistance with dissection of the corpses and analysis of biometrical and other biological data has been received from K. Koffijberg, J.J. De Leeuw and A. Wevers. Part of the project was supervised by the Project Group Ketelmeer of the Directorate Flevoland of the Ministry of Transport and Public Works. Finally, we are indebted to T.J. Boudewijn, S. Dirksen and J. Hendriks for their valuable comments on earlier drafts of this paper.

REFERENCES

Aschoff, J. & H. Pohl 1970. Der Ruheumsatz von Vögeln als Funktion der Tageszeit und der Körpergrösse. J. Orn. 11:38-47.

Dirksen, S., T.J. Boudewijn, L.K. Slager & R.G. Mes 1991. Breeding success of Cormorants *Phalacrocorax carbo sinensis* in relation to the contamination of their feeding grounds. In: M.R. Van Eerden & M. Zijlstra (eds) Proceedings workshop 1989 on Cormorants *Phalacrocorax carbo*: 233-243. Rijkswaterstaat Directorate Flevoland, Lelystad.

Everaarts, J.M., A. De Buck, M.T.J. Hillebrand & J.P. Boon 1991. Residues of chlorinated biphenyl congeners and pesticides in brain and liver of the oystercatcher (*Haematopus ostralegus*) in relation to age, sex and biotransformation capacity. The Science of the Total Environment 100:483-499.

Fox, G.A., D.V. Weseloh, T.J. Kubiak & T.C. Erdman 1991. Reproductive outcomes in colonial fish-eating birds: a biomarker for developmental toxicants in great lakes food chains. J. Great Lakes Res. 17:153-157.

Koeman, J.H., H.C.W. Van Velzen-Blad, R. De Vries & J.G. Vos 1973. Effects of PCB and DDE in cormorants and evaluation of PCB residues from an experimental study. J. Reprod. Fert., Suppl. 19:353-364.

Koffijberg, K. & M.R. Van Eerden 1995. Sexual dimorphism in the Cormorant *Phalacrocorax carbo sinensis*: possible implications for differences in structural size. Ardea 83:37-46.

Pieters, H. 1990. Dataset Ketelmeer. Gehalten van PCB's, organochloorpesticiden en totaalkwik in snoekbaars, baars, rode aal, spiering en pos over de periode 1977-1989. RIVO MO 90-206, Rijksinstituut voor Visserijonderzoek, IJmuiden.

Pieters, H. 1991. Het voorkomen van milieukritische stoffen in rode aal, driehoeksmosselen, aalscholverlevers en duikeendlevers afkomstig uit het Ketelmeergebied. RIVO MO 91-202, Rijksinstituut voor Visserijonderzoek, IJmuiden.

Platteeuw, M. 1985. Voedseloecologie van de Grote- (*Mergus merganser*) en de Middelste Zaagbek (*Mergus serrator*) in het IJsselmeergebied 1979/1980 en 1980/1981. RIJP-rapport 48 Abw, Rijksdienst voor de IJsselmeerpolders, Lelystad.

Platteeuw, M., J.H. Beekman, T.J. Boudewijn & E.C.L Marteijn 1992. Aalscholvers *Phalacrocorax carbo* in het Ketelmeer buiten de broedtijd: aantallen, prooikeuze en voedselaanbod. Limosa 65:93-102.

Platteeuw, M. & M.R. Van Eerden 1995. Time and energy constraints of fishing behaviour in breeding Cormorants *Phalacrocorax carbo sinensis* at lake IJsselmeer, The Netherlands. Ardea 83:223-234.

Scharenberg, W. & W. Schultz 1992. Kormorane (*Phalacrocorax carbo sinensis*) und Chlorkohlenwasserstoffe - Eine Untersuchung zur Ökotoxikologie und Bioindikation. Seevögel 13:47-53.

Van den Berg, M., L.H.J. Craane, S. Van Mourik & A. Brouwer 1995. The (possible) impact of chlorinated dioxins (PCDDs), dibenzofurans (PCDFs) and biphenyls (PCBs) on the reproduction of the Cormorant *Phalacrocorax carbo* - an ecotoxicological approach. Ardea 83:299-313.

Van Dobben, W.H. 1952. The food of the Cormorant in The Netherlands. Ardea 40:1-63.

Van Eerden, M.R. & B. Voslamber 1995. Mass fishing by Cormorants *Phalacrocorax carbo sinsnsis*: a recent and successful adaptation to a turbid environment. Ardea 83:199-212.

Van der Gaag, M.A., M. Van den Berg, A. Brouwer, S. Dirksen, T.J. Boudewijn & G. Van Urk 1991. Impaired breeding success of some Cormorant populations in The Netherlands: the net tightens around compounds with a dioxin-like effect. In: J.A.W. De Wit, M.A. Van der Gaag, C. Van de Guchte, C.J. Van Leeuwen & J.H. Koeman (eds) The effects of micropollutants on components of the Rhine ecosystem: 71-77. Publications and reports of the project 'Ecological rehabilitation of the River Rhine', no. 35.

Van de Guchte, K. 1993. Dansmuggelarven en aalscholvers als indicatoren van vervuild bodemslib in sedimentatiegebieden van de Rijn. De Levende Natuur 94:73-77.

Veldkamp, R. 1986. Neergang en herstel van de Aalscholver *Phalacrocorax carbo* in NW-Overijssel. Limosa 59:163-168.

Veldkamp, R. 1991. Colony development and food of Cormorants *Phalacrocorax carbo sinensis* at Wanneperveen. In: M.R. Van Eerden & M. Zijlstra (eds) Proceedings workshop 1989 on Cormorants *Phalacrocorax carbo*: 170-174. Rijkswaterstaat Directorate Flevoland, Lelystad.

Voslamber, B., M. Platteeuw & M.R. Van Eerden 1995. Solitary foraging in breeding Cormorants *Phalacrocorax carbo sinensis*: does specialised knowledge about fishing sites and fish behaviour pay off? Ardea 83:212-222.
Winkels, H.J., A. Van Diem & J. Driebergen 1990. Extent and degree of pollution of the sediment in the Ketellake. Proc. 6th Int. Congr. Int. Ass. Engineering Geol.:183-188.
Winkels, H.J. & A. Van Diem 1991. De opbouw en kwaliteit van de waterbodem van het Ketelmeer. Flevobericht 325, Rijkswaterstaat Directorate Flevoland, Lelystad.

SAMENVATTING

De lever van 23 Aalscholvers is geanalyseerd op de aanwezigheid van een aantal zware metalen en organische microverontreinigingen. De levers kwamen uit vogels die in het vroege voorjaar in vissersnetten zijn verdronken, in of nabij het Ketelmeer. Het Ketelmeer heeft een notoir verontreinigde waterbodem vanwege zijn ligging ten opzichte van de IJssel; daarom werd deze locatie gekozen.

Onderlinge verschillen in belasting konden in verband gebracht worden met leeftijd, geslacht en blijkbaar bestaande verschillen in dieetsamenstelling. Verschillen in gebiedskeuze door het jaar heen konden niet worden gekwantificeerd, maar zijn mogelijk verantwoordelijk voor enkele van de waargenomen uitschieters. Geslachtsgebonden verschillen waren over het algemeen slechts gering en gingen niet voor alle onderzochte contaminanten op.

Een vergelijking van de gevonden resultaten met gegevens over de belasting van de diverse prooivissoorten suggereerde dat een toename van het aandeel Paling in het dieet ongeveer een verdubbeling van de gehalten van enkele organochloorverbindingen tot gevolg zou kunnen hebben.